Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US05/003239

International filing date: 28 January 2005 (28.01.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/565,586
Filing date: 27 April 2004 (27.04.2004)

Date of receipt at the International Bureau: 27 June 2005 (27.06.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

World Intellectual Property Organization (WIPO) - Geneva, Switzerland
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse

1335689

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

June 20, 2005

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: ***60/565,586***
FILING DATE: ***April 27, 2004***
RELATED PCT APPLICATION NUMBER: ***PCT/US05/03239***

UNITED STATES PATENT AND TRADEMARK OFFICE
DEPARTMENT OF COMMERCE

Certified by

Jon W. Dudas

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

18304 U.S. PTO
042704

22264 U.S. PTO
60/565586
042704

PATENT

Attorney's Docket No. KENT.36640

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Assistant Commissioner for Patents
BOX PROVISIONAL APPLICATION
PO Box 1450
Alexandria, VA 22313-1450

PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 C.F.R. § 1.53(b)(2).

INVENTOR(s)/APPLICANT(s)

LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND STATE/ FOREIGN COUNTRY)
DOANE	J. WILLIAM		340 Oakwood Drive Kent, OH 44240
KHAN	ASAD	A..	901 Admore Drive Kent, OH 44240
SHIYANOVSKAYA	IRINA		4798 Heights Drive Stow, OH 44224
GREEN	ALBERT	M.	7574 Woodstown Dr. Springfield, VA 22153

TITLE OF THE INVENTION (280 characters max)

DRAPABLE LIQUID CRYSTAL DISPLAYS

CORRESPONDENCE ADDRESS

Richard A. Sharpe
PEARNE & GORDON LLP
Ohio Savings Building
12th Floor
1801 East 9th Street
Cleveland, OH 44114
Phone: (216) 579-1700
Facsimile: (216) 579-6073

STATE	Ohio	ZIP CODE	44114	COUNTRY	U.S.A.

ENCLOSED APPLICATION PARTS *(check all that apply)*

Specification *Number of Pages* *Claims Number of Pages* *Abstract Number of Pages*	16 0 0	☐ **Small Entity Status is asserted for this application by payment of the small entity fee under §1.16(k). 37 C.F.R. §1.27(c)(3).**
Drawing(s)	1	**Additional documents** *(specify)* ______

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION *(check one)*

■ A check is enclosed to cover the filing fees	**FILING FEE AMOUNT(S)** $ 160.00
☐ The Commissioner is hereby authorized to charge the filing fee to Deposit Account No. 16,0820 (our docket KENT.36640).	
■ The Commissioner is hereby authorized to charge additional filing fees and credit Deposit Account No. 16,0820 (our docket KENT.36640).	

The PTO did not receive the following listed item(s) $80.00 dollar check

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government. ☒ YES.

Respectfully submitted,

SIGNATURE: [signature]
RICHARD A. SHARPE
Reg. No. 34722

DATE: 4/27/04

Express Mail Label No. EV 081247789 US

I hereby certify that this paper (along with any referred to as being attached or enclosed) is being deposited with the U.S. Postal Service as Express Mail addressed to the Assistant Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on April 24, 2004.

By: [signature]

DRAPABLE LIQUID CRYSTAL DISPLAYS

Background of Invention:

[0001] The bistable cholesteric reflective display technology was introduced in the early 1990s as a low power, sunlight readable technology intended primarily for use on handheld or portable devices. Up until now, these displays were manufactured on glass substrates. More flexible plastic substrates have also been produced; however, what is needed in the market place is a display that has the texture of paper or fabric so that it can be an integral part of the clothing or just have the feel and utility of paper that can be rolled up, folded and easily transportable.

[0002] Such devices demand long battery lifetimes requiring the display to consume very little power. Cholesteric displays are ideal for this application as the bistability feature avoids refreshing power and high reflectivity avoids the need of power-consuming backlights. These combined features can extend battery life times from hours to months over displays that do not have these features. Reflective displays are also easily read in very bright sunlight where backlit displays are ineffective. Because the high reflective brightness of a cholesteric display and its exceptional contrast, a cholesteric display can be easily read in a dimly lit room. The wide view angle offered by a cholesteric display allows several persons to see the display at the same time.

[0003] Cholesteric liquid crystalline materials are unique in their optical and electro-optical features. Of principal significance, they can be tailored to Bragg reflect light at a pre-selected wavelength and bandwidth. This feature comes about because these materials posses a helical structure in which the liquid crystal (LC) director twists around a helical axis. The distance over which the director rotates 360° is referred to as the pitch and is denoted by P. The reflection band of a cholesteric liquid crystal is located at the wavelength, $\lambda_o = 0.5(n_e + n_o)$ and has the bandwidth, $\Delta\lambda = (n_e - n_o)P$ which is usually about 100 nm, where n_e and n_o are the extra-ordinary and ordinary refractive indices of the LC, respectively . The reflected light is circularly polarized with the same handedness as the helical structure of the LC. If the incident

light is not polarized, it will be decomposed into two circular polarized components with opposite handedness and one of the components reflected.

[0004] The cholesteric material can be electrically switched to either one of two textures, planar or focal conic. In the planar texture the helix is oriented perpendicular to the substrate to Bragg reflect light in a selected wavelength band whereas in the focal conic texture it is oriented parallel to the substrate so that the material is transparent to all wavelengths. These bistable structures can be electronically switched between each other at rapid rates (on the order of milliseconds). Gray scale is also available in that only a portion of a pixel can be switched to the reflective state.

[0005] Bistable cholesteric liquid crystal displays have several important electronic drive features that other bistable reflective technologies do not. Of extreme importance for addressing a matrix display of many pixels is the characteristic of a voltage threshold. A threshold is essential for multiplexing a row/column matrix without the need of an expensive active matrix (transistor at each pixel). Bistability with a voltage threshold allows very high-resolution displays to be produced with low-cost passive matrix technology. Gray scale capability allows stacked RGB, high-resolution displays with full-color capability where as many as 4096 colors have been demonstrated.

[0006] In addition to bistable cholesteric displays with liquid crystalline materials with a positive dielectric anisotropy, it is possible to fabricate a cholesteric display with liquid crystalline materials having a negative dielectric anisotropy as, for example, described in the US Patents 3,680,950 of Haas et al. and 5,200,845 of Crooker et al. These "negative materials" like the "positive" materials are chiral nematic liquid crystals that are prepared from nematic materials that have been twisted into a helical molecular arrangement by the addition of chiral compound or collection of chiral compounds. The negative and positive materials are prepared

from nematic liquid crystals with either a negative or positive dielectric anisotropy respectively.

[0007] Negative type cholesteric displays can be operate in a bistable mode where the material is switched into the stable planar (color reflective) texture with a with an AC pulse or into the stable (transparent) focal conic texture with a DC pulse as described by US Patent 3,680,950. There are other modes of operation such as has been disclosed by Crooker where a droplet dispersion of negative cholesteric materials is switched into the planar, color reflective texture with an applied electric field, but relaxes back into a transparent texture when the field is removed.

[0008] In the case of positive cholesteric materials, modes of operation other than a bistable mode are possible by applying a field to untwist the cholesteric material into a transparent, homeotropic texture that is transparent. Quick removal of the field transforms the material into the reflective planar texture.

[0009] Another important feature of cholesteric materials is that the RGB colors as well as IR nightvision can be stacked (layered) on top of each other without optically interfering with each other. This makes maximum use of the display surface for reflection and hence brightness. This feature is not held by traditional displays were the display is broken into pixels of different colors and only on third of the incident light is reflected. Using all available light is important observing a reflective display in a dimly lit room without a backlight. Because a cholesteric display cell does not require polarizers, low cost birefringence plastic substrates such a PET can be used. Other features, such as wide viewing-angles and wide operating temperature ranges as well as fast response times make the cholesteric technology the bistable reflective technology of choice for many applications.

[0010] Full color cholesteric displays have also been demonstrated on flexible substrates. Such displays offer the possibility of lower cost roll-to-roll manufacturing in addition to lighter weight, more rugged and conformable displays. All of the

foregoing liquid crystal materials and display configurations are intended for use in accordance with the present invention.

Description of the Invention

[0011] In this invention we describe a substantial advance in flexible liquid crystal displays whereby the displays possess drapable substrates. Such substrates include textiles or fabrics made of natural or man-made fibers such as cloth or paper, as well as drapable polymeric sheets or films. With drapable substrates, cholesteric and other liquid crystal displays offer the potential of being more flexible, rugged and even being sewed into or onto clothing to provide a wearable display. In fact, the display itself can form the material used to make the clothing or other fabric construct. A display with the texture and foldable features of a newspaper or magazine not only emulates what we are used to today, but also is more transportable. In the preferred embodiments, a new reflective display device on a drapable substrate is invented. In the past, it was normally believed that the substrate of a liquid crystal display needed to be a flat sheet of material such as glass or smooth plastic in order to achieve uniform driving voltages across the material. Nearly every commercial flat panel display manufactured and sold today is on glass substrates and the remaining few are on small rigid plastic substrates. There is a market need however, for displays that have a texture such as paper, are flexible and can be rolled up or folded like paper or cloth. The flexibility makes such a display more portable or easy to carry around and expands its applications well beyond typical information displays. Like paper, it may be rolled to fit in a pocket. Such displays may even be used on or as clothing; such as, for example, a display sewn onto a sleeve or leg that is always available for viewing while standing or sitting. Such a flexible display could also be rolled up when not in use. Thus, as used herein, drapable preferably means any material which can behave in three dimensions like cloth. For example, a drapable material is one that can bend in two dimensions simultaneously.

[0012] In this invention we disclose liquid crystal displays on substrates with rough surfaces such as cloth, textile or similar fabric like surfaces. The fabrication of these display devices involves the printing, coating or other deposition means to incorporate the liquid crystal material, display electrodes as well as insulating, barrier and other coatings onto a drapable substrate in order to achieve a that will flex with the fabric, preferably a bistable reflective display. The display materials may only appear on one side of the fabric leaving the other side untouched. Thus, in accordance a preferred embodiment there is disclosed a bistable cholesteric reflective display device that uses a drapable material, and preferably a fabric as the substrate.

[0013] In one embodiment, droplet dispersions of cholesteric material are printed or otherwise coated on a drapable material, such as a fabric. In this embodiment, the fabric is first coated with a planarization layer then coated or printed with a conducting electrode; a droplet dispersion is then coated on top of the conducting electrode followed by printing or otherwise coating and patterning of a transparent conductor such as a conducting polymer. Applying a suitable voltage across the electrodes is then used to drive the cholesteric material into either a visible color reflecting state or into a transparent state to expose the color of the fabric.

[0014] In another embodiment, droplet dispersions of cholesteric material are printed or otherwise coated on a fabric material without a planarization layer. In this embodiment, the fabric is first coated or printed with a conducting electrode; a droplet dispersion is then coated on top of the conducting electrode then followed by printing or otherwise coating and patterning of a transparent conductor such as a conducting polymer. The thickness of the coatings remains substantially constant so that they follow the contour of the fabric maintaining a substantially constant cell gap between the electrodes. Applying a suitable voltage across the electrodes is then used to drive the cholesteric material into either a visible color reflecting state or into a transparent state to expose the color of the fabric.

[0015] In still another embodiment there disclosed a high resolution display device in accordance with the aforementioned embodiments where the first conducing polymer is printed or otherwise patterned in the form of parallel strips to form rows of parallel conducting electrodes; the droplet dispersion is then coated on top of the rows of conductors; a transparent conductor is then printed, or otherwise coated and patterned, on top of the droplet dispersion in the form of conductive strips (columns) in a direction perpendicular to the rows of conductors that are under the dispersion to form a row and column matrix of electrodes with the cholesteric dispersion in between. Voltages pulses are then multiplexed in such a way to selectively address each pixel of the display formed by the intersection of each row and column. A high-resolution image is addressed on the fabric and the voltage removed with the image retained indefinitely until readdressed with another image.

[0016] In one aspect of the aforementioned embodiments an insulating or isolation layer is coated between the electrodes and the cholesteric droplet dispersion. In another aspect thereof a transparent protective coating, such as acrylic, is coated on top of the upper conductor on the viewing side.

[0017] In another embodiment the cholesteric liquid crystal material permeates the fabric by capillary action. Transparent conducting electrodes such as conducting polymers are printed or otherwise patterned on both sides of the fabric to form electrodes suitable for electrically switching the cholesteric material between its bistable planar and focal conics states to fabricate an electronically updateable color reflective display.

[0018] In one aspect of this embodiment the conducting electrodes on at least one side of the fabric also permeate into the fabric, the conducting materials being such materials as conducting polymers or carbon nano-tube materials. The conducting electrodes on the underside of the fabric do not need to be transparent.

[0019] In another aspect of this embodiment a temporary coating is first coated on the view (upper) side of the fabric, which penetrates the fabric to a prescribed depth. With the temporary coating in place, a conducting electrode material is then printed, or otherwise coated on the non-viewing (under) side of the fabric. The temporary coating is then removed and the cholesteric droplet dispersion coated in its place. Transparent conducting electrodes are then printed or otherwise coated and patterned on top of the droplet dispersion.

[0020] In still another aspect of this embodiment cholesteric liquid crystal material is allowed to permeate the fabric by dipping or by coating, printing or spraying on the fabric. In yet another aspect of this embodiment where an insulating or isolation layer is coated between the electrodes and the cholesteric droplet dispersion. Still further, it may be desirable that a transparent protective coating is coated on top of the upper conductor on the viewing side.

[0021] In some preferred embodiments, the drapable material is a fabric comprised of natural or man-made fibers. Some examples of desirable fabric materials include materials such as silk, cotton, wool, nylon, Kevlar, paper or similar material made of fibrous material formed by pressure or other means, which have the texture or drapability of cloth. In other embodiments, the drapable material can be a polymeric film or sheet which has the desired drapability.

[0022] In many preferred embodiments, the substrate material is black or some other color, whereas in others the substrate material is substantially clear and index matched to the liquid crystalline material so as to have little effect on the optics of the device. This is desirable when electrodes are disposed on opposite sides of the substrate, or where the liquid crystal material is imbibed into the substrate material.

[0023] While in the foregoing embodiments, bistable reflective cholestric liquid crystals having positive dielectric anisotropy are preferred, other liquid crystal materials may be used, such as cholesteric liquid crystals having negative dielectric

anisotropy, liquid crystals which are not bistable, positive and negative cholesterics which reflect light outside the visible spectrum and so on.

[0024] In fabricating the devices of the invention, the preferred liquid crystalline layers will be in the form of a cholesteric droplet dispersion. The liquid crystal can be microencapsulated, formed by phase separation methods such as polymerization induced phase separation (PIPS), solvent induced phase separation (SIPS) or temperature induced phase separation (TIPS), or be formed by emulsion methods as described below.

[0025] There are many different approaches to encapsulation, some of which have been used for cholesteric liquid crystals. One such process is phase separation, which is basically a process that involves mixing the cholesteric liquid crystalline material with a pre-polymer solution then polymerization under suitable conditions to form a dispersion of droplets in a polymer binder. Polymerization and hence droplet formation occurs after the material mixture has been coated. There are basically three types of polymerization techniques that can be used depending on the polymer (or monomer): (1) thermally induced phase separation (TIPS); (2) polymerization induced phase separation (PIPS); and, (3) solvent induced phase separation (SIPS).

[0026] The thermally induced phase separation (TIPS) process has been used to show that a cholesteric material will maintain its bistability and electro-optical features when encapsulated into a droplet structure [US Patent 6,061,107]. The TIPS system is a binary mixture of a liquid crystal and a thermoplastic (polymer). The mixing interaction energy is positive. At high temperature, the mixing entropy term is large and dominant; the system is in a homogeneous form, which has a lower free energy. As temperature is lowered, the mixing entropy becomes smaller, and the liquid crystal phase separates to form droplets in order to reduce the total free energy. The droplet size can be controlled by the cooling rate with smaller droplets being formed at faster cooling rates. TIPS is advantageous in controlling droplet size because cooling rates are easily adjusted. Furthermore, the system can be thermally

cycled many times and different droplet sizes can be obtained in the same sample using different cooling rates. There are many thermoplastic polymers that can be used for this process. Some examples are PMMA (poly methyl methacrylate), which provides a tangential anchoring condition and PIMB (poly isobutyl methacrylate), which provides a perpendicular anchoring condition.

[0027] Polymerization induced phase separation (PIPS) starts with a homogeneous mixture of a prepolymer (monomer) and a liquid crystal. As the monomers are polymerized, the number of possible configurations of the monomers decreases and thus the mixing entropy decreases. When the degree of polymerization reaches a critical value, the liquid crystal phase separates from the polymer. The polymerization can be thermalinitiated or photo-initiated. In thermal-initiated polymerization, the monomers are typically combinations of epoxy resins and curing agent thiol, such as Epon 828 (Shell Chemical) or Capcure 3800 (Miller Stephenson Company). The mixture coated at room temperature can then be cured at an elevated temperature. Smaller droplets are formed at higher temperatures or higher concentrations of epoxy resins because of the higher reaction rate.

[0028] In photo-polymerization, monomers with acrylate or methyacrylate end groups, such as Norland 65 (which is a combination of acrylate monomers and photo-initiators), are used. Some photo-initiators are also needed. Upon absorbing a photon, the photo-initiator becomes a free radical, which reacts with the acrylate group and results in an opened double bond. The opened double bond reacts with another acrylate group. The chain reaction propagates until the opened double bond reacts with another opened double bond or another free radical, and then the polymerization stops. In sample preparation, the mixture is printed or coated then cured under the irradiation of uv light. Smaller droplets are formed under higher uv irradiation.

[0029] In the SIPS method, the initial material is a mixture of a liquid crystal and a thermoplastic dissolved in a common solvent. When the concentration of the

solvent is sufficiently high, the mixing interaction energy of the system is negative, and the components are homogeneously mixed. As the solvent evaporates, the mixing interaction energy increases. At a sufficiently low concentration of the solvent, the system phase separates to reduce the mixing interaction energy. The droplet size of the liquid crystal depends on the solvent evaporation rate with smaller droplets obtained at faster evaporation rates.

[0030] Another very different encapsulation process involves emulsification of a cholesteric liquid crystal in water with a waterborne polymer. Encapsulation of cholesteric liquid crystals by emulsification was practiced even before the invention of bistable cholesteric displays. As early as 1970, cholesteric materials were emulsified for making cholesteric thermal and electrical responsive coatings [US Patent 3,600,060]. More recently, emulsification methods have been refined to making cholesteric droplets that are very uniform size [US Patent 6,423,368 B1]. The most common emulsification procedure basically involves a liquid crystal being dispersed in an aqueous bath containing a water-soluble binder material such as de-ionized gelatin, polyvinyl alcohol (PVA) or polyethylene oxide (PEO). Water acts as a solvent and dissolves the polymer to form a viscous solution. This aqueous solution does not dissolve the liquid crystal, and they phase separate. When a propeller blade at a sufficiently high speed stirs this system, the micron size liquid crystal droplets are formed. Smaller liquid crystal droplets form at higher stirring speeds [P. Drzaic, *Liquid Crystal Dispersions,* World Scientific Publishing Co., Singapore (1995)]. The molecular weight of the water-soluble polymer is also a factor affecting the droplet size. Larger droplets form with lower molecular weight. After the droplets are formed, the emulsion is coated on a substrate and the water is allowed to evaporate. There are many different emulsification procedures; however, the one primarily followed for liquid crystalline materials is basically the process described above using PVA. The emulsification method has the advantage that the droplet dispersions may contain a very high percentage of cholesteric material.

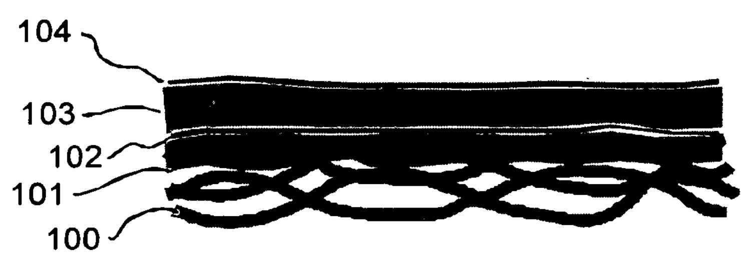
[0031] It will be apparent from the foregoing that while the principal advantages of the invention are realized by the presentation of a drapable liquid crystal display, a principal contributor to the realization of this advantage is the provision of an electrically addressable liquid crystal display on a single substrate. Known electrically addressable displays employ at least two substrates which, as noted above, are generally rigid, with the liquid crystal sandwiched between them. In accordance with the present invention, a display element on a single substrate is fabricated by sequence of coatings consisting of droplet dispersions, transparent conductive coatings, insulation coatings, isolation coatings etc. Instead of laminating an upper substrate to complete the display element, a final sequence of coatings or printings consisting of a patterned conducting electrode such as a conducting polymer followed by an isolation coating and a hard or protective coat are coated to finalize construction of the display element. The protective coat and isolation coat may be combined into one coating. The coating of the upper conductive electrodes and a hard coat avoids the lamination of an upper substrate. The display element can consist of several coatings of droplet dispersions with different color or twist handedness as desired for multiple colors or high brightness. Such a display configuration on a single substrate improves the flexibility of the display and improves its brightness and contrast. It also improves the ruggedness of the display in that the protective coat is more difficult to delaminate than an upper laminated substrate. Thus, one embodiment of the invention contemplates the ability to form a display using only a single, preferably flexible, substrate even where that substrate is not drapable.

[0032] In carrying out the invention it will also be possible to prepare a display on a remote substrate and then transfer it to the desired substrate such as a drapable fabric. In this case, a sequence of multiple coatings involving droplet dispersions, transparent conductive coatings, insulation coatings, isolation coatings, etc. that are necessary to formulate a complete display device are coated on a substrate from which the coated sequence can be removed upon drying or curing. The removed film now is a display element in itself without any substrate. The display film can then be laminated onto any object or material to which electrodes can be applied for

connection to drive electronics. The back side of the display film may be used for printing all or a portion of the drive electronics as the printed electronic technology permits.

Description of the Preferred Embodiments

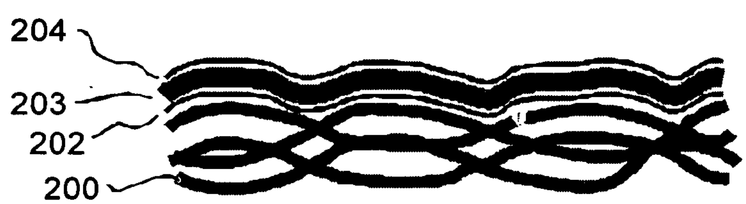
[0033] As noted above, in one embodiment (see Figure 1) the fabric, 100, is over coated with a layer of material, 101, which serves to provide a flat planar surface on which to coat the lower conducting electrode, 102, which is preferably black but may be any other color depending on the desired background color of the display. The cholesteric droplet dispersion, 103 is then coated or printed on top of the lower conductor. It may be desired to coat an intermediate insulation layer between the lower conductor and the droplet dispersion. An upper transparent conductor, 104, is then coated or printed on top of the droplet dispersion. In order to prevent electrical shorting between electrodes, it may be necessary to coat an intermediate insulating layer between the droplet dispersion, 103, and the upper transparent electrode, 104.



[0034] Figure 1 Illustration of a fibrous material with an over coating of a layer of polymeric serving to planarize the surface. The electrode materials, droplet dispersions and protective hard coats are then coated on the planarization layer; where 100 = fabric material, 101 = planarization layer, 102 = lower conducting electrode, 103 = cholesteric droplet dispersion, 104 = upper transparent conducting electrode. As will be apparent in view of this disclosure, the coatings and liquid crystal layers

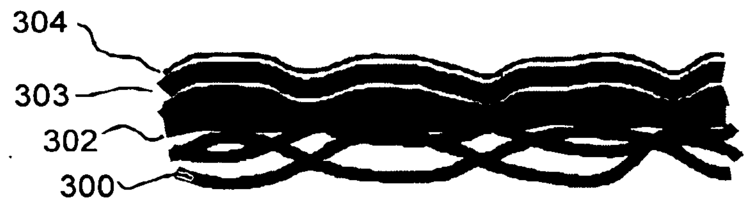
can be repeated one or more times to produce a stacked display.

[0035] Another embodiment (see Figure 2) eliminates the planarization layer with the lower electrode material, 202 coated or printed on the fabric, 200, generally following the contour of the fabric. A coating may precede the lower electrode coating to provide adherence of the conducting material to the fabric. The cholesteric droplet dispersion, 203, is then printed or coated on top of the lower conductor in which the dispersion follows the contour of the lower electrode with substantially constant thickness throughout. An upper transparent conducting electrode, 104, is then printed on top of the dispersion. Insulating layers may be coated between the droplet dispersion and the upper and lower conductors to prevent electrical shorts.



[0036] Figure 2: Illustration of a fibrous material in which the electrode materials, droplet dispersions and protective hard coats are coated over the fabric, substantially following the contour of the surface of the fabric such that the inner electrode spacing containing the droplet dispersion remains substantially constant.

[0037] In the foregoing embodiment, the lower conducting material may penetrate the fabric as illustrated in Figure 3. The upper surface, however, may not be flat and follow somewhat the contour of the upper surface of the fabric.



[0038] Figure 3: Illustration of the embodiment in which the lower conducting electrode, 302, penetrates into the fabric leaving an upper surface on which to coat or print the droplet dispersion, 303.

[0039] In a another embodiment (see Figure 4), capillary action draws the cholesteric material, 403 into the fabric, 400, at a constant depth. The bistable cholesteric liquid crystalline material is absorbed in the fabric either in its raw or microencapsulated form. In this embodiment, it may be necessary to first deposit (prior to the droplet dispersion) a temporary coating on the view upper side of the fabric, which penetrates the fabric to a prescribed depth. With the temporary coating in place, a conducting electrode, 402, is then printed, or otherwise coated on the non-viewing under side of the fabric. The temporary coating is then removed and the cholesteric droplet dispersion coated in its place. Transparent conducting electrodes, 404 are then printed or otherwise coated and patterned on top of the droplet dispersion.

[0040] Figure 4: Illustration of the cross section of a fabric based cholesteric display in which the cholesteric liquid crystal is absorbed into the fibrous material with conducting electrode on both sides of the dispersion.

[0042] In each of the embodiments, it may be necessary or desirable to coat a durable protective coat(s) on top of the upper transparent conductor to insure a rugged display suitable for use and to provide a seal or protection of the display against the environment.

[0043] Although the most basic elements of the preferred displays of the invention are a drapable substrate, a liquid crystal layer and a pair of electrodes, a preferred display configuration is shown in Fig. 5, where CP1 and CP2 signify conductive polymer layers and the gel layers serve as insulation layers, as well as to protect the other display layers from the preferred acrylic paint protective layer. Of course, one advantage to many fabrics or textiles is that they are breathable. However, the coatings used to produce the displays of the invention might deleteriously effect the breathability of the material in the region of the display. This can be remedied by the formation of micro-holes or the like in the area of the display.

[0044] As noted, preferably at least one side of the fabric is smooth. The material can be manufactured this way, such as with a neoprene coating, or it can be made this way by any number of chemical or physical treatments, such as chemically modifying the surface, adding layers or coatings, adding layers and removing them to modify the surface, heating, irradiating, mechanically rolling and so on.

[0045] One advantage of a fabric display is that the electrodes need not necessarily lie on one side of the substrate, but instead can be run through and connections made at the back of the substrate. Thus, the conductors can be hooked up to the display through the fabric. There are potentially many methods of applying the conductors including ink jet or spray printing onto the fabric using a mask or stencil, spin coating, pretreating the surface to form a chemical mask which allows the

electrode material to only stick to certain areas, chemically or mechanically deactivating regions of conductive material and so on. In fact, it is contemplated that even the fabric itself can be manufactured as the conductor. In a preferred embodiment, the fabric would be made such that it conducts in only one direction.

[0046] In view of the instant disclosure, those of ordinary skill in the art will be able to appropriately select any contact or non-contact method of applying the conductors and other coatings in accordance with the present invention.

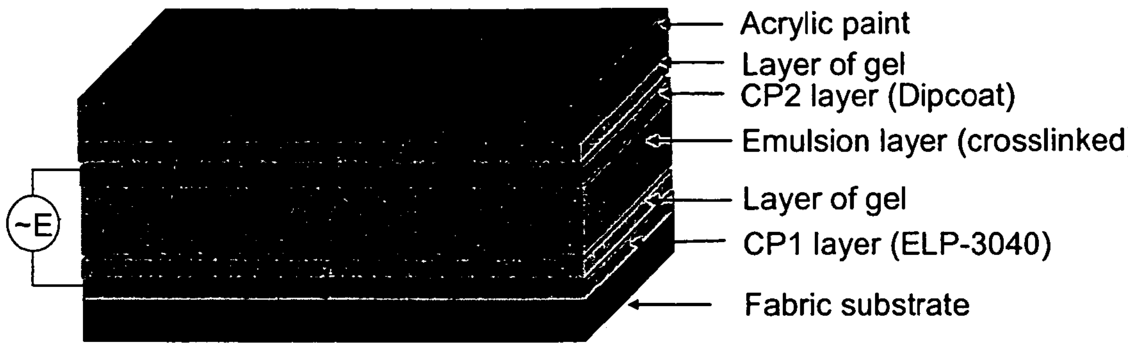

Acrylic paint
Layer of gel
CP2 layer (Dipcoat)
Emulsion layer (crosslinked)
Layer of gel
CP1 layer (ELP-3040)
Fabric substrate
~E

Fig. 5